

A STUDY ON THE VOCs EMISSION RATES OF HOME ELECTRICAL APPLIANCES

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ABSTRACT

Home electrical appliances release hazardous chemical substances produced by the effects of heating during their operation. The present study investigated the emission rates of chemical substances on home electrical appliances such as microwave ovens, vacuum cleaners, electric heaters, electric blankets, multimedia players, electronic dictionaries, MD players and notebook PCs.

The VOCs emission rates of comparatively small products were measured using a small-scale environmental chamber with a volume of 0.065 [m³]. Toluene was found to be emitted from all samples, at rates of 0.15 to 9.5 [μ g/h · unit]. In a previous study, increased chemical substance emission rates were detected during the operation of electrical space heaters, but in the present study no such increase was detected in any of the electrical appliances studied, except for the notebook PC.

For comparatively large products, measurements were conducted using a large-scale environmental chamber with a volume of 4.98 [m³]. The VOCs concentrations in this chamber rose during operation for all products. The emission rates of total VOCs ranged from 9.3 to 2600 [μ g/h · unit]. Microwave ovens revealed a markedly large emission rate of 2600 [μ g/h · unit] after 45 minutes of operation.

KEYWORDS

Indoor air pollution, VOC, Home electrical appliance, Emission rates

INTRODUCTION

Home electrical appliances release hazardous chemical substances produced by the effects of heating during their operation. Preliminary research has reported the release of chemical pollutants from home electrical appliances. For example, the characteristics of chemical substance emissions from electrical space heaters were investigated and their emission rates have been quantitatively determined (Nozaki and Asano 2005). The emission rates differed greatly among similar kinds of appliance and there were appliances which generated chemical substances even when they were not operating.

The emission of DEP and DBP has been reported from the component parts of notebook PCs. Styrene was detected from the keyboard, and a large amount of toluene was released from the monitor (Kato et al. 2005).

The pollutants emitted by new electric ovens have been reported and significant quantities of formaldehyde exceeding occupational exposure guidelines were reported for two ovens (S. K. Brown et al. 2005). This report warned that the 4-hour 'burn off' time recommended by manufactures was insufficient to prevent initial domestic emissions.

The purpose of the present study is to clarify the emission characteristics of, and to determine the emission rates of chemical substances released from home electrical appliances.

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METHOD

Test sample

The home electrical appliances tested are listed in Table 1. 16 home electrical appliances were selected for testing. They were all new products and were manufactured one month before the experiment. The day before the experiment start, tested appliances were operated in an experimental room where the environmental conditions were controlled at the temperature of 25 ± 1 degree and the relative humidity of 40 ± 10 percent and the ventilation rate of 0.50 ± 0.05 air exchange per hour. So, the initial emissions were investigated in the experiment.

Experimental laboratory

According to each product size, two kinds of experimental chamber were used. One was a small-scale environmental chamber with a volume of $0.065 \text{ [m}^3\text{]}$, and the other was a large-scale environmental chamber with a volume of $4.98 \text{ [m}^3\text{]}$. The outline of each chamber system is shown in Figures 1 and 2, respectively.

Both chambers were installed in an environmental laboratory at Tohoku Bunka Gakuen University and could be controlled for four environmental conditions: temperature, relative humidity, ventilation rate and airflow velocity. In the experiments reported they were controlled for a temperature of 28 ± 1 degree Celsius, relative humidity of 50 ± 5 percent, ventilation rate of 0.50 ± 0.05 air exchange per hour and airflow velocity of $0.2\text{-}0.3 \text{ [m/s]}$. Also, in both chambers, filtered air was always supplied. In order to ensure the perfect mixing, a mixing fan was operated in the large-sized chamber.

Table 1. Test samples

Test sample	Size[mm]	Power consumption[W]
Microwave oven A	W305×D480×H408	1200
Microwave oven B	W330×D483×H400	1280
Microwave oven C	W317×D490×H397	1360
Vacuum cleaner A	W220×D256×H287	1000
Vacuum cleaner B	W214×D256×H288	1000
Electric table heater	W290×D290×H45	600
Electric blanket	W1400×D850×H12	20
Multi listening player A	W52×D86×H15	3
Multi listening player B	W50×D50×H15	3
Multi listening player C	W71×D112×H16	3
MD player A	W84×D81×H21	0.15
MD player B	W76×D78×H15	0.10
Electronic dictionary A	W140×D94×H16	0.45
Electronic dictionary B	W144×D99×H13	0.40
Electronic dictionary C	W140×D106×H20	0.43
Notebook PC	W271×D209×H28	60

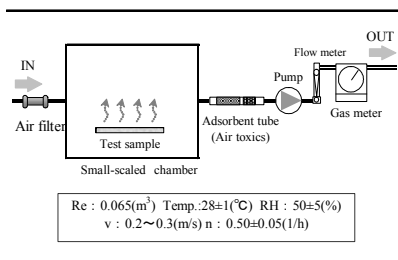


Figure 1. Small environmental chamber

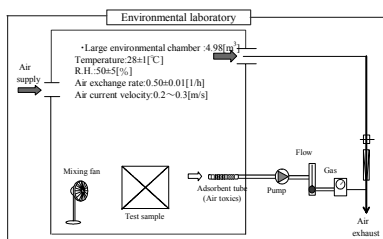


Figure 2. Large environmental chamber

Sampling and analysis method

The sampling and analysis methods for detecting and measuring VOCs were as follows.

Method: Solid-phase sampling-thermal desorption-gas chromatography/mass spectrometry (GC/MS)

Sampler: Carbon tube

Thermal desorption unit: Perkin Elmer Co. Ltd, Turbo Matrix ATD

GC/MS: Perkin Elmer Co. Ltd, Turbo Mass Gold

Calculation of emission rates

The chemical substance emission rates can be calculated by the following three methods.

1) The method of calculating the emission rates from the concentration in a steady state is shown in equation (1).

$$M = Q(C_{ss} - C_o) \quad (1)$$

Here, M is the chemical substance emission rate, Q is the amount of room ventilation, C_{ss} is the chemical substance concentration in a steady state, and C_o is the chemical substance concentration of air supplied to the chamber. If the emission rates were constant, the emission rates can be computed using this equation and the steady state concentration measured by the experiment.

2) The method of calculating the emission rates from the concentration at an arbitrary time is shown in equation (2).

$$M = \frac{(Q + \alpha R)(C - C_1 e^{-(n+\alpha)t})}{1 - e^{-(n+\alpha)t}} - QC_o \quad (2)$$

Here, α is adsorption rate, R is the volume of the chamber and C_1 is the initial concentration in the chamber. The emission rates computed from this equation means the averaged emission rates by that time.

3) The 3rd is the method using concentration displacement (dC) during a given time interval (dt). Even when emission rates were expressed as a function of time (t), the emission rates at an arbitrary time can be calculated by using this equation (3).

$$M = \frac{\Delta C m R}{e^{-mt} (1 - e^{-m\Delta t})} + mRC_1 - QC_o \quad (3)$$

Here, ΔC is the displacement concentration over a certain time interval, Δt , and $m = (Q + \alpha R)/R$.

In the present study, the emission rates were calculated by equations (1) and (2).

Since the precision of measured concentration is $0.50 [\mu\text{g}/\text{m}^3]$ and the ventilation rates of $4.98 [\text{m}^3]$ chamber and $0.065 [\text{m}^3]$ chamber were $2.5 [\text{m}^3/\text{h}]$ and $0.033 [\text{m}^3/\text{h}]$, respectively, so the precision of calculated emission rates by equation (1) can be expressed within $1.2 [\mu\text{g}/\text{h}]$ in the experiment using $4.98 [\text{m}^3]$ chamber and $0.017 [\mu\text{g}/\text{h}]$ in the experiment using $0.065 [\text{m}^3]$ chamber.

RESULTS

Microwave oven

The TVOC emission rates of microwave ovens ranged from 16 to 120 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ at the time of its un-operating and was changed to 2600 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ at the maximum with its operation (Figure 3 to 5). Increase of the emission rates was shown with their operation. And the emission of benzene and toluene were detected in all samples.

Vacuum cleaner

As shown in Figures 6 and 7, the TVOC emission rates for the vacuum cleaners ranged from 8.1 to 15 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ when not operating and rose to a maximum of 750 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ after 60 minutes of operation. Emission rates increased with the duration of operation. The emission of toluene was detected in all samples.

Electric heater and electric blanket

When switched off, the TVOC emission rate for the electric heater was 18 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ and that of the electric blanket was 2.6 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ (Figures 8 and 9). The TVOC emission rate of the electric heater rose to 29 $[\mu\text{g}/\text{h} \cdot \text{unit}]$ and that of the electric blanket rose to 8.4 $[\mu\text{g}/\text{h} \cdot \text{unit}]$. Emission rates for both

therefore increased markedly when operating. Also, the emission of butanol was detected from the electric heater, and p-dichlorobenzene was detected from the electric blanket.

Multi listening player

As shown in Figures 10 to 12, multi listening players produced few emissions, with TVOC emission rates ranging from 0.21 to 0.69 [$\mu\text{g}/\text{h} \cdot \text{unit}$]. The emission of a few μg of toluene was detected in all samples.

MD player

MD players also produced few emissions, with TVOC emission rates ranging from 1.5 to 1.6 [$\mu\text{g}/\text{h} \cdot \text{unit}$], as shown in Figures 13 and 14. A small amount of toluene emission was detected.

Electronic dictionary

TVOC emission rates of electronic dictionaries ranged from 2.3 to 6.4 [$\mu\text{g}/\text{h} \cdot \text{unit}$], as shown in Figures 15 to 17. Emissions of toluene and dichloromethane were detected in all samples

Notebook PC

As shown in Figure 18, TVOC emission rates of notebook PC was 5.6 [$\mu\text{g}/\text{h} \cdot \text{unit}$] when switched off, rising to 23 [$\mu\text{g}/\text{h} \cdot \text{unit}$] after 8 hours of operation. Emissions of both toluene and butanol were detected.

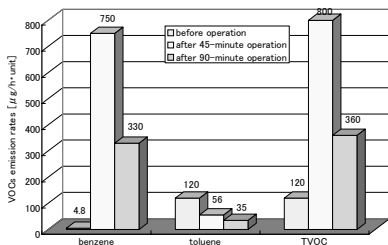


Figure 3. The VOCs emission rates (Microwave oven A)

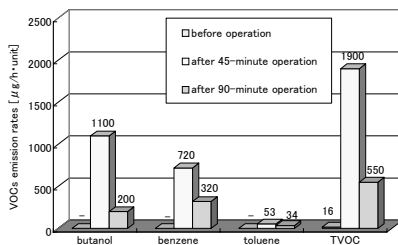


Figure 4. The VOCs emission rates (Microwave oven B)

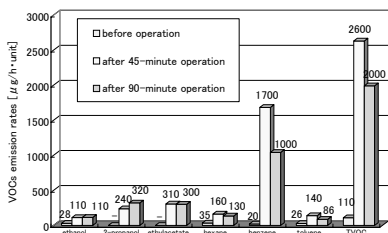


Figure 5. The VOCs emission rates (Microwave oven C)

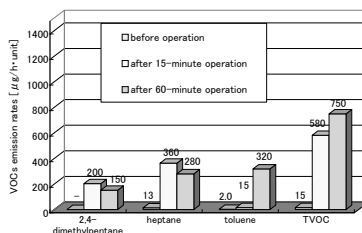


Figure 6. The VOCs emission rates (Vacuum cleaner A)

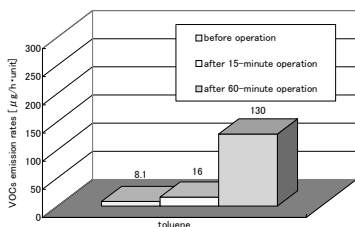


Figure 7. The VOCs emission rates (Vacuum cleaner B)

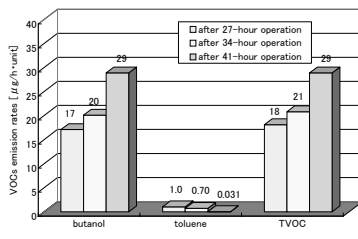


Figure 8. The VOCs emission rates (Electrical heater)

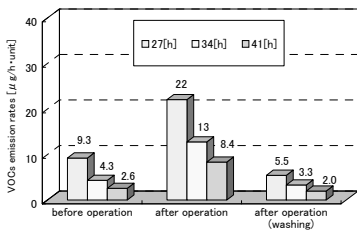


Figure 9. The VOCs emission rates (Electrical blanket)

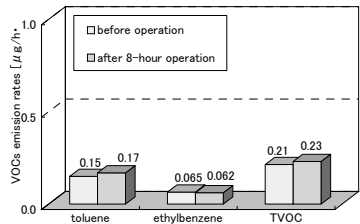


Figure 10. The VOCs emission rates (Multi listening player A)

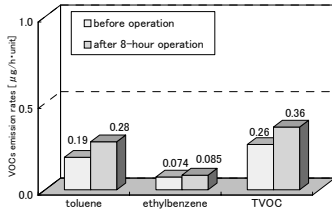


Figure 11. The VOCs emission rates (Multi listening player B)

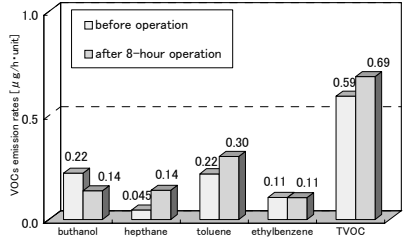


Figure 12. The VOCs emission rates (Multi listening player C)

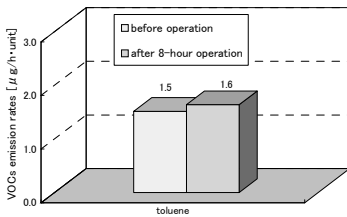


Figure 13. The VOCs emission rates (MD player A)

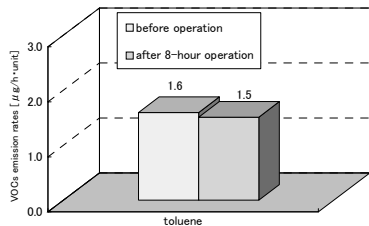


Figure 14. The VOCs emission rates (MD player B)

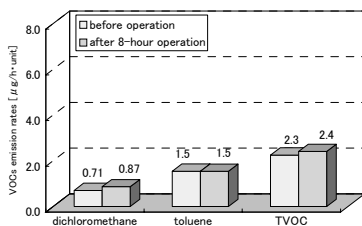


Figure 15. The VOCs emission rates (Electronic dictionary A)

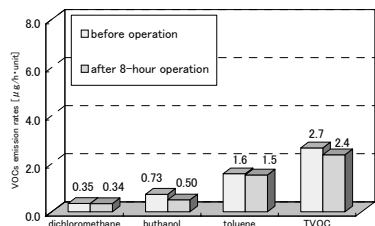


Figure 16. The VOCs emission rates (Electronic dictionary B)

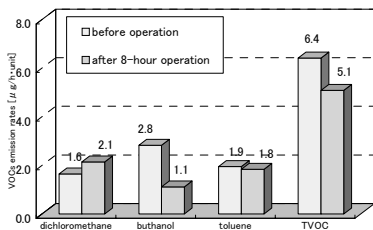


Figure 17. The VOCs emission rates (electronic dictionary C)

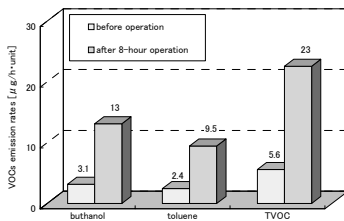


Figure 18. The VOCs emission rates (notebook PC)

CONCLUSIONS

1. Emissions of benzene and toluene were detected from the microwave ovens and there was marked emission of benzene. The emission rates of TVOC ranged from 16 to 2600 [μg/h · unit].
2. Emission of butanol was detected from the vacuum cleaners, which showed TVOC emission rates of 8.1 to 750 [μg/h · unit].
3. In comparatively large products, such as microwave ovens and vacuum cleaners, the emission rates were larger than for other samples measured.
4. Emission of butanol was detected from the electric heater and p-dichlorobenzene was detected from the electric blanket.
5. CD and other music players and MD players had very low VOCs emissions and the emission rates hardly changed when the apparatus was in operation.
6. The emissions of toluene and dichloromethane were detected from the electronic dictionaries with TVOC emission rates ranging from 2.3 to 6.4 [μg/h · unit].
7. Toluene was emitted from the notebook PC, with TVOC emission of 5.6 [μg/h·unit] when switched off, rising to 23 [μg/h · unit] after 8 hours of operation.

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